

# State of New Hampshire

## Inter-Department Communication

**Date:** February 12, 2004

**From:** Phil Trowbridge  
Coastal Scientist

**At (Office):** Environmental Services  
Watershed Management

**Subject:** Probabilistic Assessments of Water Quality in NH's Estuarine Waters

**To:** Gregg Comstock, Supervisor, Water Quality Planning Section

The purpose of this memorandum is to summarize the results of probabilistic assessments of water quality for New Hampshire's estuarine waters. Probability based monitoring uses randomly assigned stations to take an unbiased sample of a natural resource. Statistics from the sample can be used to make inferences about conditions throughout the resource. The major advantage of this approach is that 100% of the resource can be assessed at minimal cost. The biggest disadvantage is that the specific locations of water quality violations cannot be inferred from the sample. Therefore, the results of the probabilistic assessment must be used in concert with the deterministic assessments of individual assessment units in the Assessment Database (ADB).

This memorandum describes the methods used to develop probabilistic assessments for NH's estuaries and the results. In addition, the predicted results from the probabilistic assessments are compared to the actual results from the ADB. Tables containing the required data elements for reporting probabilistic data for the Section 305(b) Report are included as an appendix.

### Methods

#### *Data Source*

The data source for these assessments is the EPA National Coastal Assessment dataset from 2000 to 2003. The National Coastal Assessment is a five year monitoring effort funded by the U.S. Environmental Protection Agency and implemented by NHDES and the University of New Hampshire. Each coastal state was monitored using a consistent suite of indicators and a probabilistic monitoring design so that an accurate assessment of the nation's coastal resources could be completed.

#### *Study Area*

In New Hampshire, the National Coastal Assessment study area covers the entire Great Bay Estuary and the Hampton/Seabrook Estuary. This resource was overlain by a grid of 80 equal area hexagons for the 2000-2001 seasons and 82 equal area hexagons for the 2002-2003 seasons. Within each hexagon, random sampling locations were generated using ArcInfo software. Field teams from the University of New Hampshire collected samples from 76 of the 80 hexagons in 2000-2001. Two of the hexagons in the study design were incorrect because they exclusively covered freshwaters and so were removed from the study design. The other two missing locations were not sampled because the local conditions made sampling impossible (e.g., heavy surf). During the 2002-2003 seasons, the field teams collected samples at 75 of the 82 hexagons.

The National Coastal Assessment study area includes waters in the State of Maine. Since the Section 305(b) report is only concerned with NH's waters, the stations in Maine were excluded from the analyses in this memorandum. Following guidance from EPA's Atlantic Ecology Division, only those stations that actually fell in NH waters and only the area of NH waters in each hexagon were used in the analysis. Out of the 78 stations in the original study design for 2000-2001, 60 stations were from NH waters. Similarly, 70 of the 82 stations from the 2002-2003 study design were in NH waters. These stations are the basis for the probabilistic assessments of the 17.7 square miles of estuarine waters in NH.

Figures 1 and 2 illustrate the overlap between the resource area used by EPA to assign the sampling locations for the National Coastal Assessment and the estuarine assessment units in the ADB for Hampton-Seabrook Harbor and the Great Bay Estuary, respectively. There are small areas of difference between the two geographic information files. However, given the overall size of the resource, the two geographic information files overlap reasonably well. Therefore, the probabilistic assessments made from the National Coastal Assessment data will be assumed to be representative of 100% of the estuarine area in the 49 estuarine assessment units in the ADB.

#### *Statistical Methods*

Estimates of the percent of the resource meeting assessment criteria were made using the Horvitz-Thompson Estimator Method for a continuous resource with a known subpopulation size (see Methods 1 and 10 in EPA, 1996). Confidence intervals on the estimates were generated for the 95% percentile.

#### *Environmental Indicators*

Three designated uses were assessed using the NCA dataset: aquatic life use support, primary contact recreation, and secondary contact recreation. The core indicators for aquatic life use support are dissolved oxygen, pH, and sediment quality. For primary and secondary contact recreation, the only core indicator is enterococcus.

These indicators were evaluated at each of the stations to determine whether the station should be classified as Fully Supporting, Insufficient Information, or Not Supporting per the NHDES Consolidated Assessment and Listing Methodology (CALM) (NHDES, 2004). For aquatic life use support, Table 1 illustrates how the results from the three indicators were combined to classify individual stations.

**Table 1: Decision Rule for Aquatic Life Use Support Classifications**

<b>Criteria</b>	<b>Classification</b>
If all three of the indicators met state standards	Fully Supporting
If any of the three indicators violated state standards	Not Supporting
If data were missing for any of the three indicators but none of the available data violated state standards	Insufficient Information
If no data were available for any of the three indicators	Not Assessed

The probabilistic assessments for aquatic life use support deviated from the requirements in the CALM in two ways. First, sample size requirements were waived since the results at all the stations would be aggregated. And, second, daily average dissolved oxygen data were not required. Per the CALM, assessments of dissolved oxygen should use data on both instantaneous DO concentrations (in mg/L) and daily average measurements of DO (in %sat). Since the NCA dataset consisted of grab samples for water quality, daily average DO data were not available.

This exception is warranted since most of the documented violations of the DO standard in the estuarine assessment units were captured with instantaneous DO readings, not daily averages.

The evaluation of sediment quality involved sediment chemistry, sediment toxicity, and benthic community data. None of the stations were shown to be impaired. The station evaluations are summarized in Trowbridge (2004).

For primary and secondary contact recreation, the following decision tree was used to make use support classifications.

**Table 2: Decision Rule for Primary and Secondary Contact Recreation Classifications**

<b>Criteria</b>	<b>Classification</b>
If the predicted enterococcus concentration was less than 75% of the geometric mean criterion	Fully Supporting
If the predicted enterococcus concentration was greater than the single sample maximum criterion	Not Supporting
If the predicted enterococcus concentration was between 75% of the GMC and SSMC	Insufficient Information
If no data were available for enterococcus	Not Assessed

As with aquatic life use support, the sample size requirements at each individual station from the CALM were waived because the results from all the stations were aggregated. In addition, geometric mean concentrations of enterococcus were not calculated because stations were not visited more than once during the field season. The CALM states that a Fully Supporting assessment can be made in the absence of a geometric mean concentration if all the single samples have concentrations that are less than 75% of the geometric mean criterion. Therefore, 75% of the geometric mean criterion was used as the threshold below which the waters would be considered fully supporting.

If more than one results for a parameter was available for a station, one of the results was randomly chosen for inclusion in the analyses. For enterococcus, the first result at the station was used. For DO and pH, the analyses included the results that were associated with the station visit when all the other water quality parameters were measured.

For reference, the distributions of the individual water quality indicators measured by the National Coastal Assessment are presented in Appendix B. These indicators include: Dissolved oxygen, pH, chlorophyll-a, enterococcus, nitrogen (NH<sub>4</sub>), nitrogen (NO<sub>2</sub>+NO<sub>3</sub>), phosphorus (PO<sub>4</sub>), and silica. The results in Appendix B are for the entire estuarine system which includes both New Hampshire and Maine Waters. Data for all the parameters except enterococcus were collected during the 2000-2001 sampling seasons. Enterococcus data were collected during the 2002-2003 seasons.

Figure 1

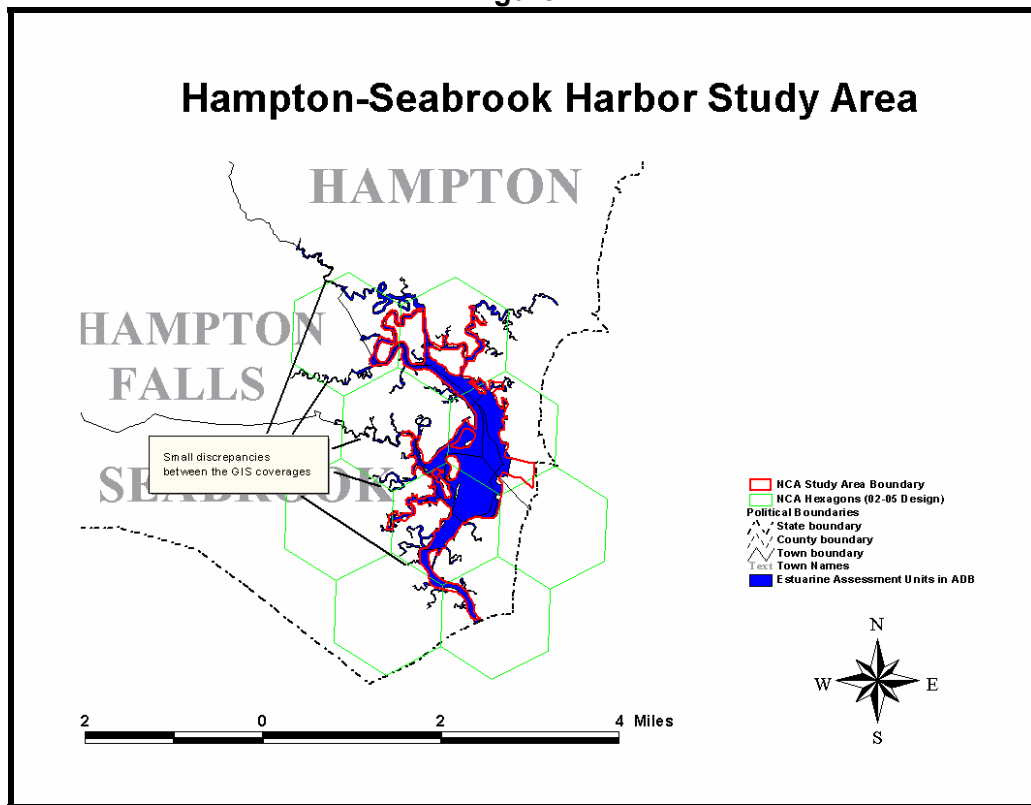
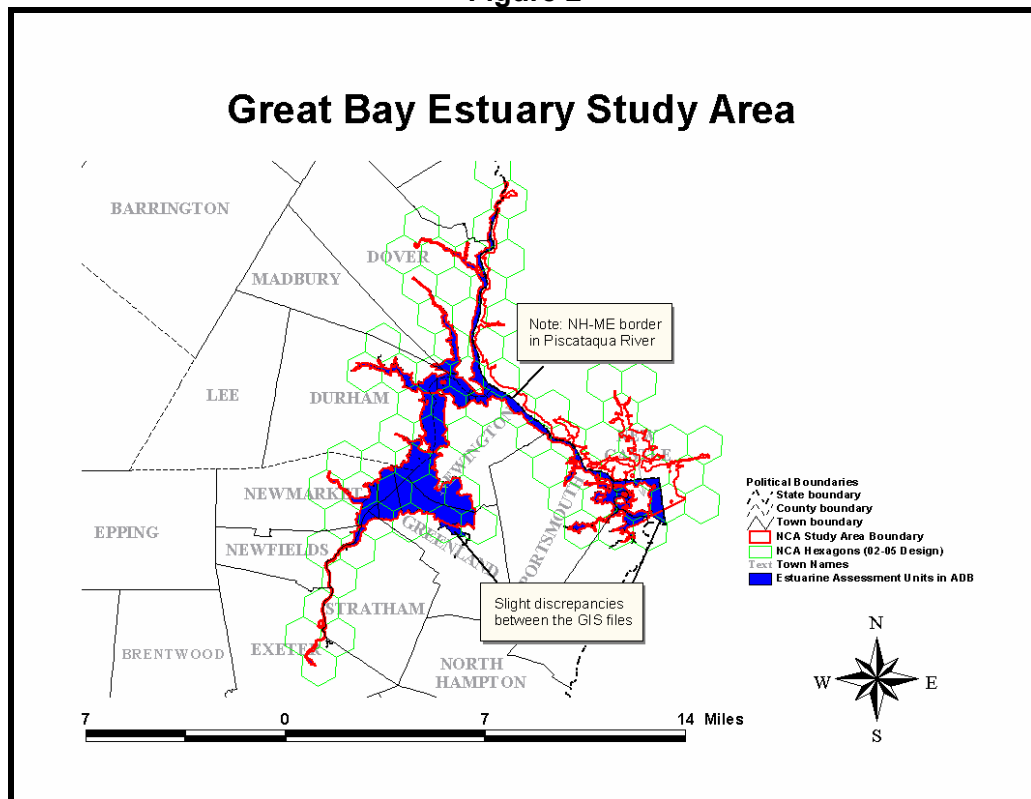


Figure 2



## Results

The results of the statistical analysis are shown in the following tables and figures.

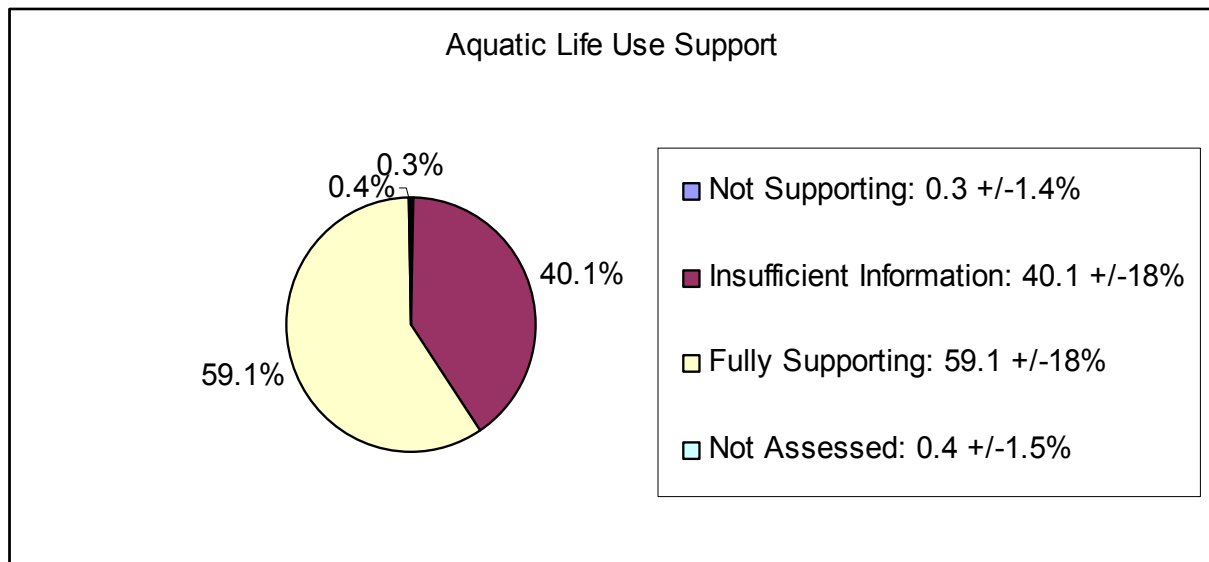
### *Aquatic Life Use Support*

**Table 3: Classifications of NH Estuarine Waters for Aquatic Life Use Support**

Category	Percent	Lower CI*	Upper CI*	Square miles
Not Supporting	0.35%	0.00%	1.76%	0.06
Insufficient Information	40.13%	22.12%	58.14%	7.10
Fully Supporting	59.11%	41.09%	77.13%	10.46
Not Assessed	0.42%	0.00%	1.94%	0.07
Total	100.00%			17.70

\* Lower and Upper CI: Lower and upper bounds of the 95<sup>th</sup> percentile confidence limits of the percentage.

**Figure 3: Percent of NH Estuarine Waters in each Aquatic Life Use Support Classification**



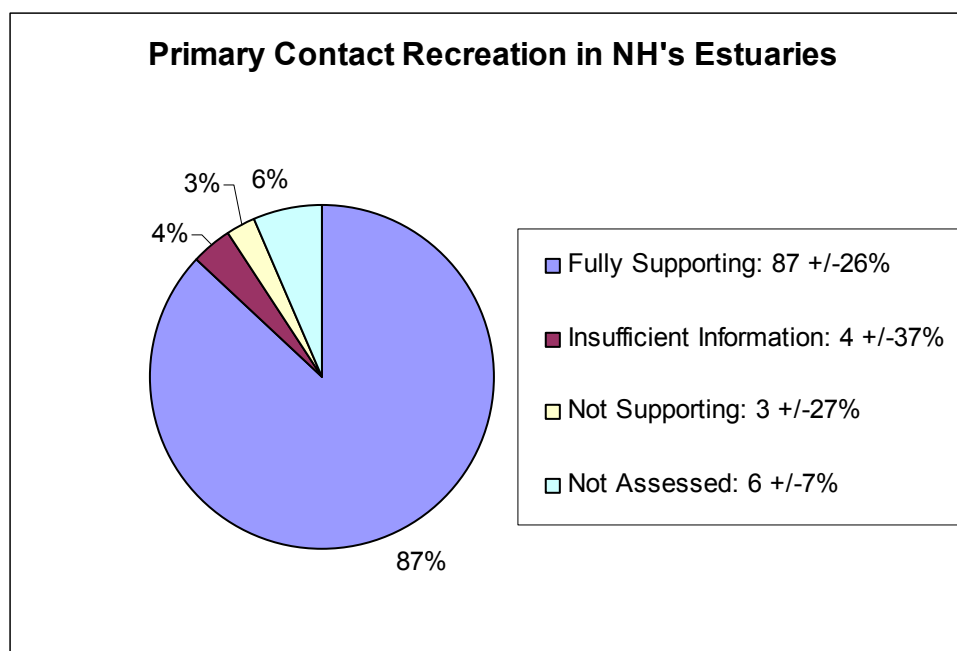
## Primary Contact Recreation

**Table 4: Classifications of NH Estuarine Waters for Primary Contact Recreation**

Category	Percent	Lower CI*	Upper CI*	Square miles
Not Supporting	2.82%	0.00%	29.53%	0.50
Insufficient Information	3.93%	0.00%	40.67%	0.70
Fully Supporting	86.83%	60.76%	100.00%	15.37
Not Assessed	6.41%	0.00%	13.00%	1.14
Total	100.00%			17.70

\* Lower and Upper CI: Lower and upper bounds of the 95<sup>th</sup> percentile confidence limits of the percentage.

**Figure 4: Percent of NH Estuarine Waters in each Primary Contact Recreation Classification**



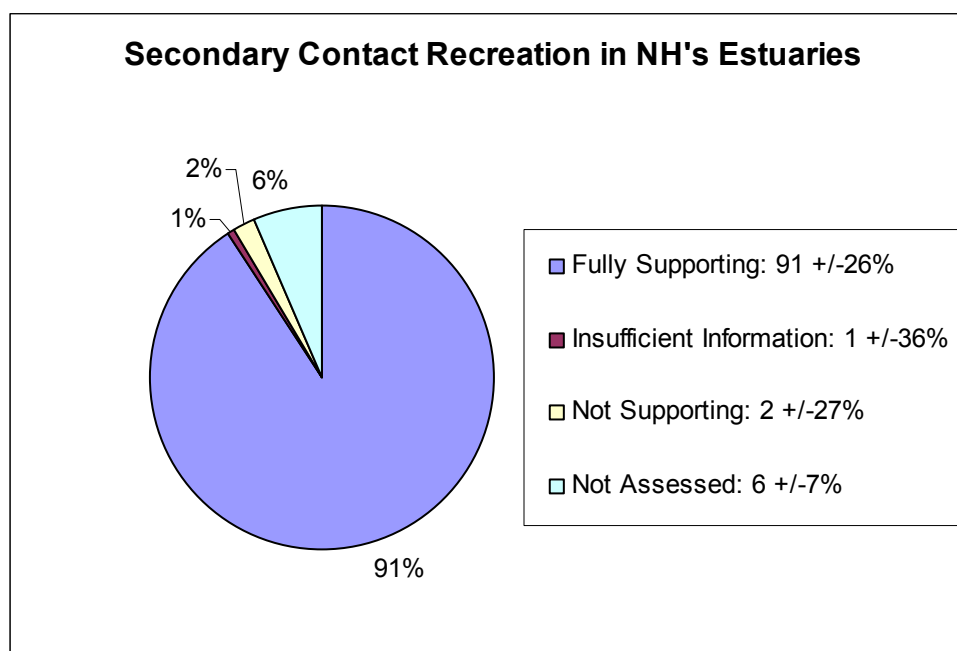
## Secondary Contact Recreation

**Table 5: Classifications of NH Estuarine Waters for Secondary Contact Recreation**

Category	Percent	Lower CI*	Upper CI*	Square miles
Not Supporting	2.13%	0.00%	28.78%	0.38
Insufficient Information	0.70%	0.00%	37.26%	0.12
Fully Supporting	90.76%	64.89%	100.00%	16.06
Not Assessed	6.41%	0.00%	13.00%	1.14
Total	100.00%			17.70

\* Lower and Upper CI: Lower and upper bounds of the 95<sup>th</sup> percentile confidence limits of the percentage.

**Figure 5: Percent of NH Estuarine Waters in each Secondary Contact Recreation Classification**



## Discussion

### *Aquatic Life Use Support*

A very low percentage of the estuary was found to be Not Supporting for aquatic life use support (0.3%). The reason for these Not Supporting areas was low dissolved oxygen (3.6 mg/L, 4.7 mg/L) at two of the 60 stations sampled. None of the measurements of pH and sediment quality showed violations of State standards.

The large proportion of the estuary (40%) that is listed as Insufficient Information is also due to dissolved oxygen. A sensor error during the 2000 season caused the dissolved oxygen data from CTD casts to be lost at 23 stations. In contrast, there were only five sites at which either the pH or the benthic community data was missing. During the 2002-2005 sampling cycle, dissolved oxygen will be collected at all the NCA stations to fill this data gap.

Despite these problems with the dissolved oxygen measurements, nearly 60% of the estuary was shown to be Fully Supporting for aquatic life use support. This estimate matches the consensus of local researchers and state officials that NH's estuaries are generally well oxygenated and supporting of aquatic life.

Finally, two of the stations in the original study design were not sampled for any of the parameters. The absence of any data for these stations resulted in the classification of 0.4% of the estuary as Not Assessed.

The results of the probabilistic and deterministic assessments are summarized in the following table. This comparison shows that the two methods produce statistically different estimates of the area of estuarine waters classified as both Fully Supporting and Not Supporting. Assuming that the probabilistic methods are an unbiased representation of the estuarine conditions, the comparison shows that the deterministic methods over predict the impaired area (2.43 sq miles vs. 0-0.31 sq miles) and slightly under predict the fully supporting area (6.77 sq miles vs. 7.27-13.65 sq miles). As data becomes available for the stations that are currently classified as Insufficient Information, the differences between the assessments may change. However, the initial results demonstrate that the assessment units for the estuaries may not be representative of actual conditions. For example, assessment units have been assumed to be homogeneous with regards to water quality. If water quality violations only occur in a small area of the assessment unit but the whole assessment unit is listed as impaired, then the amount of the estuary that is listed as impaired will be inflated.

**Table 6: Comparison of Probabilistic and Deterministic Assessments for Aquatic Life Use Support**

Category	Probabilistic Assessment (95%ile Conf. Int.)	Deterministic Assessment
Not Supporting	0 - 0.31	2.43
Insufficient Information	3.91 - 10.29	7.82
Fully Supporting	7.27 - 13.65	6.77
Not Assessed	0 - 0.34	0.69
Total	17.70	17.7

Units: Square miles



### *Primary Contact Recreation*

Most of the estuary (87%) was found to be Fully Supporting for primary contact recreation. In contrast, only 3% of the estuarine area had enterococcus concentrations greater than State water quality standards (104 #/100ml). Enterococcus data were missing for 5 of the 70 stations in the 2002-2003 study design. As a result, 6% of the estuary was unassessed.

Similar to aquatic life use support, the probabilistic assessments show a statistically higher percentage of Fully Supporting waters than the deterministic assessments. For the rest of the classifications, the two assessment methods produced the same result given the confidence limits on the probabilistic estimates.

**Table 7: Comparison of Probabilistic and Deterministic Assessments for Primary Contact Recreation**

<b>Category</b>	<b>Probabilistic Assessment (95%ile Conf. Int.)</b>	<b>Deterministic Assessment</b>
Not Supporting	0 - 5.23	4.18
Insufficient Information	0 - 7.2	4.37
Fully Supporting	10.75 - 17.7	8.66
Not Assessed	0 - 2.3	0.49
Total	17.70	17.70

Units: Square miles

### *Secondary Contact Recreation*

For secondary contact recreation, almost all of the estuarine areas that were assessed were found to be Fully Supporting (91%). Two percent of the estuary did not meet the acceptable criterion of 520 #/100ml from the CALM. Note that only 3% of the estuary exceeded the State water quality standard of 104 #/100ml for primary contact recreation. Therefore, most areas that are Not Supporting for primary contact recreation are also Not Supporting for secondary contact recreation.

Table 8 shows that the results of the probabilistic and deterministic assessments for all classifications are the same within the confidence limits of the probabilistic estimates.

**Table 8: Comparison of Probabilistic and Deterministic Assessments for Primary Contact Recreation**

<b>Category</b>	<b>Probabilistic Assessment (95%ile Conf. Int.)</b>	<b>Deterministic Assessment</b>
Not Supporting	0 - 5.09	0.15
Insufficient Information	0 - 6.59	0.69
Fully Supporting	11.48 - 17.7	13.34
Not Assessed	0 - 2.3	3.52
Total	17.70	17.70

Units: Square miles

## References

EPA (1996). EMAP Statistical Methods Manual. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Corvallis OR. May 1996.

NHDES (2004b) Consolidated Assessment and Listing Methodology, Draft Update. NH Department of Environmental Services, Concord, NH. *In preparation*.

Trowbridge PR (2004) Sediment Quality in New Hampshire's Estuaries: An evaluation of the 2000-2001 National Coastal Assessment Dataset. NH Department of Environmental Services, Concord, NH. February 4, 2004.

## Appendix A: Section 305(b) Reporting Data Elements

**Table A1: Aquatic Life Use Support**

Data Element	Result
Probabilistic Network Name	National Coastal Assessment (Coastal 2000)
Project ID (Assessment Unit ID)	49 assessment units starting in "NHEST" (see list in Table A4)
Target Population	NH's estuarine resources
Resource Type	Estuary
Designated Use	Aquatic Life Use Support
Indicator	Dissolved Oxygen, pH, Sediment Quality
Size	17.7
Units	Square miles
Number of sites	60 stations in NH. There are also 18 station on the Maine side of the border. These stations will be included in estuary-wide assessments but were not included in this assessment.
Percent attaining	59.1%
Percent insufficient information	40.1%
Percent not attaining	0.3%
Data	2000 and 2001 field season data
Confidence	+/-18%

**Table A2: Primary Contact Recreation**

Data Element	Result
Probabilistic Network Name	National Coastal Assessment (Coastal 2000)
Project ID (Assessment Unit ID)	49 assessment units starting in “NHEST” (see list in Table A4)
Target Population	NH’s estuarine resources
Resource Type	Estuary
Designated Use	Primary Contact Recreation
Indicator	Enterococcus
Size	17.7
Units	Square miles
Number of sites	70 stations in NH. There are also 12 station on the Maine side of the border. These stations will be included in estuary-wide assessments but were not included in this assessment.
Percent attaining	87%
Percent insufficient information	4%
Percent not attaining	3%
Data	2002 and 2003 field season data
Confidence	+/-37%

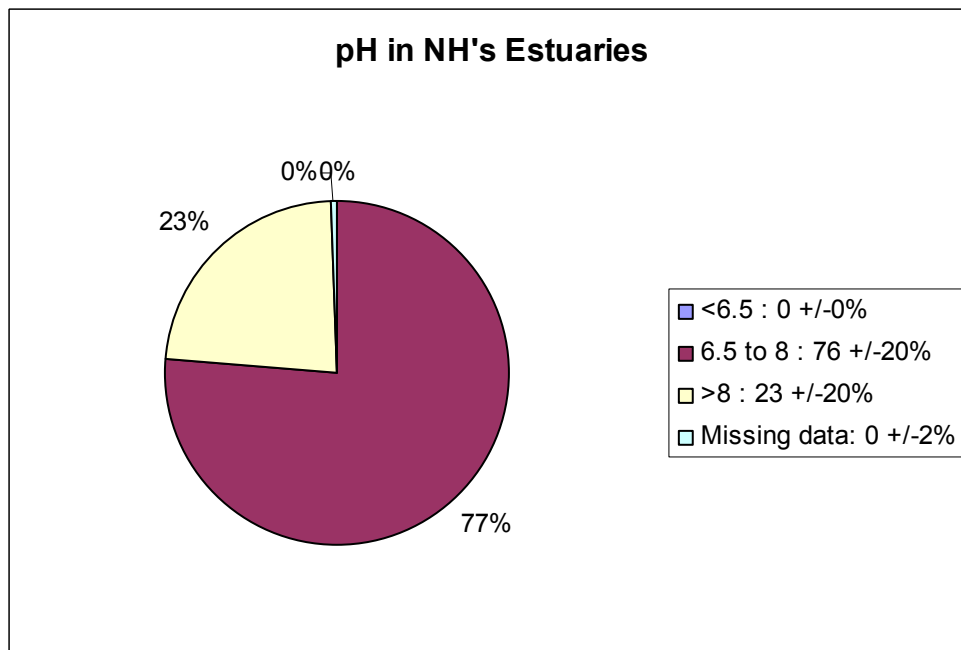
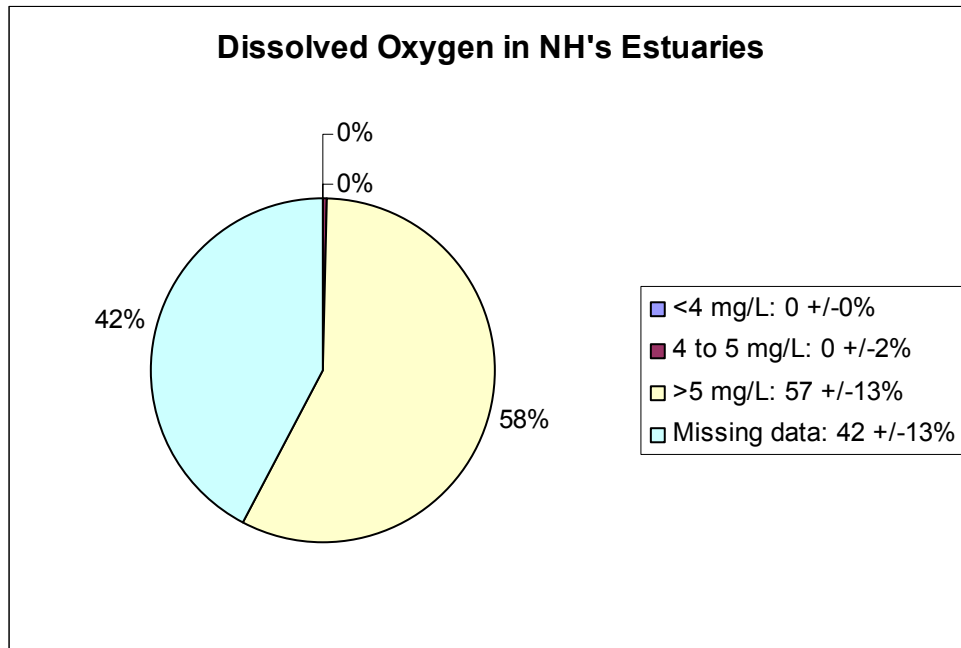
**Table A3: Secondary Contact Recreation**

Data Element	Result
Probabilistic Network Name	National Coastal Assessment (Coastal 2000)
Project ID (Assessment Unit ID)	49 assessment units starting in "NHEST" (see list in Table A4)
Target Population	NH's estuarine resources
Resource Type	Estuary
Designated Use	Secondary Contact Recreation
Indicator	Enterococcus
Size	17.7
Units	Square miles
Number of sites	70 stations in NH. There are also 12 station on the Maine side of the border. These stations will be included in estuary-wide assessments but were not included in this assessment.
Percent attaining	91%
Percent insufficient information	1%
Percent not attaining	2%
Data	2002 and 2003 field season data
Confidence	+/-36%

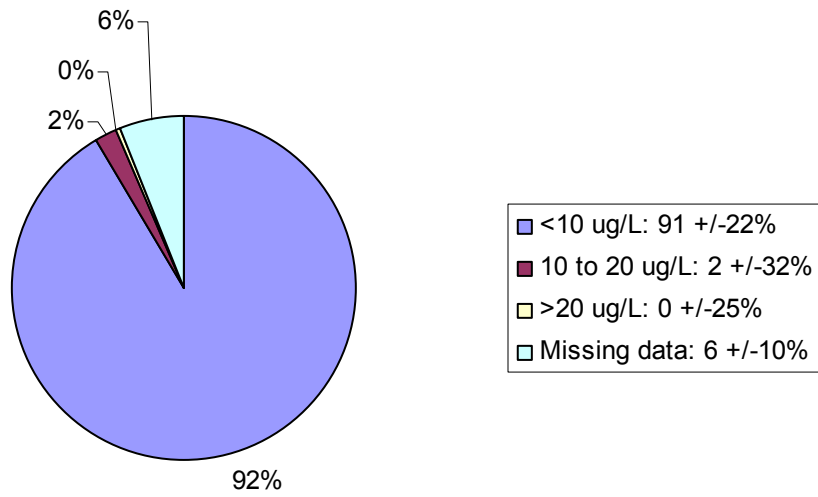
**Table A4: Assessment Units covered by the National Coastal Assessment Study Area**

Assessment Unit ID	Square Miles
NHEST600030406-01	0.2831
NHEST600030608-01	0.2472
NHEST600030709-01	0.1602
NHEST600030806-01	0.4788
NHEST600030902-01-01	0.0021
NHEST600030902-01-02	0.0154
NHEST600030902-01-03	0.4460
NHEST600030903-01	0.6755
NHEST600030904-01	0.1929
NHEST600030904-02	0.6907
NHEST600030904-03	1.1585
NHEST600030904-04	4.7363
NHEST600030904-06-04	0.0251
NHEST600030904-06-05	0.0438
NHEST600030904-06-06	0.1671
NHEST600030904-06-07	1.7945
NHEST600030904-06-08	0.8598
NHEST600031001-01	0.6546
NHEST600031001-02	1.1125
NHEST600031001-03	0.1497
NHEST600031001-04	0.1191
NHEST600031001-05	0.6586
NHEST600031001-08	0.0230
NHEST600031001-09	0.0253
NHEST600031001-10	0.1229
NHEST600031001-11	0.7205
NHEST600031002-01	0.1458
NHEST600031002-02	0.3092
NHEST600031003-01	0.0111
NHEST600031003-02	0.0327
NHEST600031003-03	0.0463
NHEST600031003-04	0.0039
NHEST600031004-01-01	0.0709
NHEST600031004-01-02	0.0438
NHEST600031004-02-01	0.0108
NHEST600031004-02-02	0.0184
NHEST600031004-02-03	0.0194
NHEST600031004-02-04	0.0211
NHEST600031004-03-01	0.0338
NHEST600031004-03-02	0.0536
NHEST600031004-04-01	0.1391
NHEST600031004-05	0.0721
NHEST600031004-06	0.0250
NHEST600031004-07	0.0490
NHEST600031004-08-01	0.1085
NHEST600031004-08-02	0.1110
NHEST600031004-09-03	0.6044
NHEST600031004-09-04	0.1934
NHEST600031004-09-05	0.0057
Total	17.7

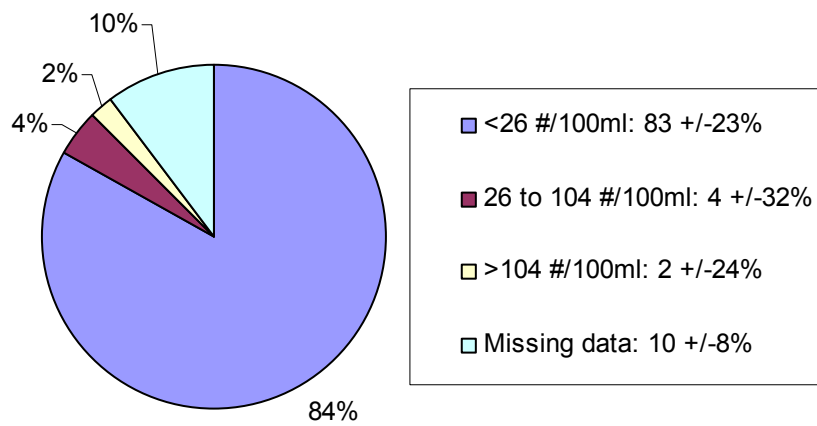
## Appendix B: Distributions of Individual Water Quality Indicators in NH and ME waters



### Chlorophyll-a in NH's Estuaries

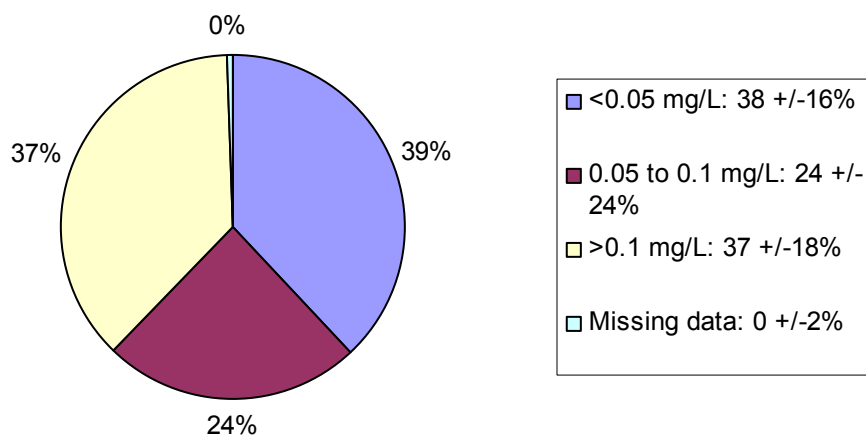


### Enterococcus in NH's Estuaries

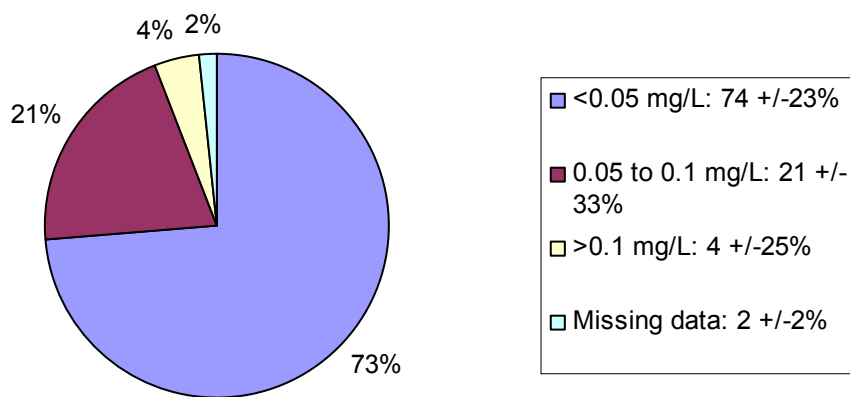




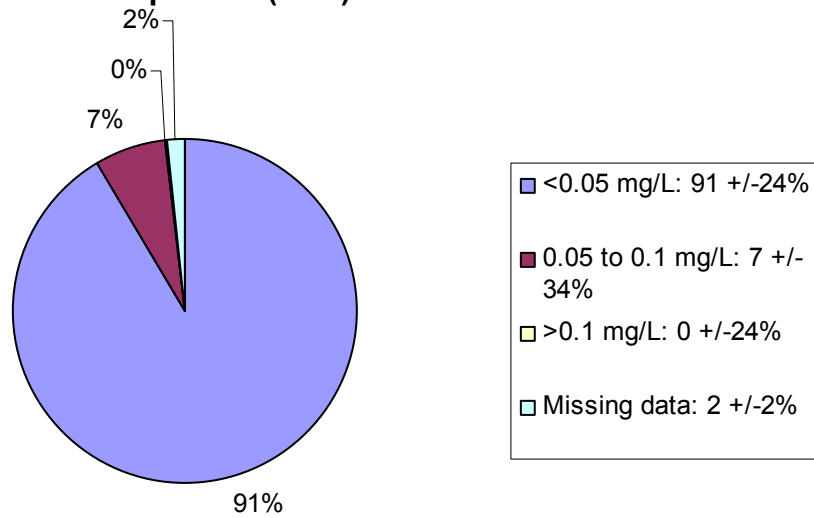
### Nitrogen (NH<sub>4</sub>) in NH's Estuaries



### Nitrogen (N<sub>2</sub>+NO<sub>3</sub>) in NH's Estuaries



### Phosphorus (PO<sub>4</sub>) in NH's Estuaries



### Silica in NH's Estuaries

